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INFLUENCE OF LOADING CONDITION ON PILOTING TECHNIQUE

FOR SPIN RECOVERY FOR PURSUIT AIRPLANES

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## NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

## RESTRICTED BULLETIN

INFLUENCE OF LOADING CONDITION ON PILOTING TECHNIQUE  
FOR SPIN RECOVERY FOR PURSUIT AIRPLANES

By H. A. Soule and Oscar Seidman

## SUMMARY

Recent information as to the influence on spins and spin recovery of the wing loading and load distribution of present-day pursuit airplanes is discussed for the guidance of pilots. It is pointed out that high wing loadings and rearward center-of-gravity locations make for more difficult spin recoveries. The high wing loadings also result in high rates of descent and large control forces for recovery. The position of the ailerons may have a considerable effect on both the steady spin and the recovery. The optimum position of the aileron depends on the relative weight carried in the fuselage and along the wings and may change with the expenditure of load in flight. Unless conditions for a particular airplane are completely understood, therefore, care should be taken to maintain the ailerons neutral.

## INTRODUCTION

Reference 1 gives an adequate discussion of general piloting technique for recovery from spins and should prove invaluable reading for all pilots who may have occasion to recover from spins. Since the publication of reference 1, however, there have been changes in airplane design as well as increased experience in spinning, both in flight and in the free-spinning wind tunnel. For modern pursuit or fighter airplanes, for example, the overall size and weight have greatly increased and, with the installation of numerous wing guns, the percentage of the weight carried in the wings has also increased. The purpose of the present paper is to restate some of the points made in reference 1 with a change of emphasis occasioned by consideration of the high wing loadings and load distributions of present-day pursuit airplanes.

Only upright spins have been considered, as these spins represent the type most commonly encountered. In the spin tunnels, inverted spins appear to present little difficulty as regards recovery characteristics. Difficulties encountered in flight with inverted spins are believed largely attributable to the awkward position of the pilot, the difficulty of applying full control deflections, and the confusion resulting from the inverted position.

A good deal of the information summarized in the present paper is based upon detailed discussions given in references 1 to 5. Other papers of fundamental interest with regard to spinning are references 6 and 7.

#### EFFECT OF WING LOADING

One noteworthy recent design trend has been the increase of the airplane weight supported by a given wing area. A systematic investigation carried out in the spin tunnel has indicated that as the wing loading is increased the spins tend to become flatter, the rate of descent higher, and the recovery slower. For the designer, the layout of a tail giving satisfactory recoveries becomes more difficult with these increased wing loadings.

For the pilot, even if the tail arrangement is adequate, the higher wing loadings will be associated with a higher rate of descent during the spin and a greater altitude loss during recovery. Some of the increase in the rate of descent as compared with older designs is attributable to the increased cleanliness. For fully loaded pursuit airplanes, rates of descent of 300 miles per hour at 10,000 feet (equivalent to 18,000 ft/min or an indicated airspeed of 170 mph) should not be unusual. At this rate the altitude loss per turn is about 650 feet (6500 ft for a 10-turn spin). With allowance for the entry and recovery, deliberate spins should not be started at less than 15,000 feet.

In connection with the suggested minimum spinning altitude of 15,000 feet, it is of interest to note that an increase in altitude increases the difference between the densities of the airplane and the air and has much the same effect on the spin as an increase in wing loading. Recovery thus becomes increasingly difficult as the altitude is increased.

The high speeds on the flight path appear to be directly responsible for the high control forces that have been reported by pilots, although the increase in overall airplane size also contributes to this condition. Inasmuch as control force varies as the square of the speed, it will be readily appreciated that what is a reasonable force at 100 miles per hour may become impossibly large when increased four times, as is the case if the speed is increased from 100 to 200 miles per hour.

In anticipation of possible high control forces and possible oscillatory motion in spins, the safety belt and the control adjustments should be arranged to enable the pilot to exert maximum effort. A short pilot may require pedal blocks to enable him to apply full rudder deflection.

From measurements made on a tail surface at angles of attack corresponding to the angles encountered in spins, it appears that the trim tab should be of considerable aid in lightening the control forces for recovery when the pilot is experiencing difficulties. The pilot, however, should be prepared to readjust the tab immediately upon recovery to avoid overcontrolling in the ensuing dive.

#### EFFECT OF DISTRIBUTION OF LOAD

Spin-tunnel tests on a large number of models have indicated that the effectiveness of each of the airplane controls in spin recoveries is dependent on the distribution of load. When the loads are carried mainly in the fuselage, as is the case for older single-engine pursuit airplanes with fuselage fuel tanks and synchronized guns, the rudder is the predominant control during spin recovery. Deflecting the ailerons with the spin, that is, placing the stick to the right in a right spin, is likely to steepen the spin, put the inner wing down, and expedite recovery. The effect of elevator depends mainly on how it interferes with the flow over the rudder. Down-elevator positions generally are detrimental because these positions increase the "shadow" of the horizontal surfaces on the rudder. Experience in flight has indicated that great benefit is derived from the elevators if they are put down briskly after the rudder has been reversed.

When considerable weight is carried in the wing, as is the case with the increased use of unsynchronized wing guns and the advent of the multiengine pursuit airplane, the rudder becomes less effective and the elevator more effective, while the optimum position for the ailerons is reversed. There have been one or two extreme instances for multiengine pursuit airplane models in which rudder reversal would not produce recovery although the results indicated that recovery could be accomplished by movement of either the ailerons or elevator, even though the rudder remained set for the spin. There have been flight reports indicating several instances where, even for the older single-engine airplanes, the elevator was the predominant control for recovery.

It is especially important to realize that, as the proportion of the load carried in the fuselage is reduced and the proportion carried in the wing is increased, the importance of the aileron setting first becomes negligible and then increases again but with reversed effects. When considerable weight is distributed along the wings, it is essential to avoid placing the ailerons with the spin, that is, stick to the inside of the spin. Pilots have, however, reported cases where the stick tended to move toward the inside of the spin. If the pilot does not know which direction of aileron deflection will give best recovery, he should therefore consciously keep the stick centralized rather than let it float off to the position of zero lateral force.

Because a large proportion of the weight carried in the wings may be in the form of fuel, ammunition, and bombs and may be expended in flight, the same airplane may exhibit either set of characteristics discussed in the preceding paragraphs, depending on the instantaneous loading. This fact is important to the pilot because control movements that are beneficial for one flight-loading condition may prevent recovery for another. Because of these possible changes in the spin during flight, it is not considered advisable for the pilot to attempt to use the ailerons during recovery unless he has a complete understanding of the characteristics of the particular airplane and a knowledge of changes of weight distribution during the flight.

## INFLUENCE OF CENTER-OF-GRAVITY LOCATION

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Tests in the spin tunnel have shown that rearward positions of the center of gravity are adverse for spinning just as they are for stability. When the center of gravity is moved to the rear, the spins become flatter and recoveries slower. Some airplanes are relatively insensitive to the effect of center-of-gravity location while others may be markedly affected. Because both the spin and the general stability characteristics are improved by a forward movement of the center of gravity, it is desirable to use up first the expendable items of load which are located farthest back. For example, by first using fuel from the rear tank, the pilot can move the center of gravity forward during flight. On the other hand, by using the fuel or ammunition from the location forward of the center of gravity, he may adversely affect the spin characteristics even though the airplane is getting lighter.

## RECAPITULATION

Reference 1 gives the following general recommendations for operation of control for recovery from a spin, presupposing that the ailerons are held neutral throughout the recovery:

1. Briskly move the rudder to a position full against the spin.
2. After a lapse of appreciable time, say after at least  $1/2$  additional turn has been made, briskly move the elevator to approximately the full down position.
3. Hold these positions of the controls until recovery is effected.

To these recommendations it seems desirable to add for the service pilot:

4. Be certain that the ailerons remain neutral during both the spin and the recovery, even though a side force to the stick is required to hold them there.
5. Be sure that the throttle is closed when the spin is started.

With regard to the second recommendation it should be appreciated that under some conditions, the effect of the elevator movement may predominate in recovery and that it is not always best to wait until the nose starts to drop before putting the stick forward. Leading with the rudder by about a half turn, however, is desirable in case the rudder movement is most important, as the lapse of time will give the rudder a better chance to act before the blanketing is increased by the down movement of the elevator. The brisk movements are recommended because of the dynamic effect of the sudden changes in moments resulting from the use of the controls.

The fourth recommendation appears desirable, even though the optimum aileron deflection is known for the loading at the start of a flight, because of change of loading with expenditure of fuel, ammunition, and bombs and because of the possible serious consequences of the wrong deflection. Under certain circumstances, as in flights specifically made for test spinning, it may be desirable to use the aileron setting giving the most rapid recovery.

#### CAUTIONS FOR FLIGHT SPIN TESTING

The Army and the Navy require model spin tests of all their airplanes of the pursuit and fighter category. Before the pilot undertakes flight spin tests of a new airplane, it is recommended that he acquaint himself with the findings of the model tests, which show the best control manipulation for various loadings for both the clean and the landing conditions. For the first spin tests, the airplane should be as light as possible and the center of gravity as far forward as possible. Consideration should be given to the load distribution in this condition to determine the best aileron deflection to be applied. Alternate control manipulations for use in emergency should be decided upon and rehearsed.

The prolonged spin should be approached with caution by making successive spins of increasing duration with increments of about 1/4 turn in each direction, until it is apparent that there is no further change in the spin condition with increased number of turns. For all spins, observations should be made of the relative effectiveness of the rudder and ailerons and a checkup on the increase

of speed and on rudder, elevator, and aileron forces during the initial stages of the spin should be made.

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If the pilot observes either very high or very low control forces when he attempts recovery, he should be especially cautious, although low stick forces do not necessarily indicate that the controls will be ineffective. It is desirable to use a change in the spin itself as a criterion of control effectiveness. The pilot should not, however, wait for the rudder to take hold and the nose of the airplane to drop before applying the elevator in present pursuit airplanes. Once the complete recovery procedure has been followed, the pilot should wait at least 5 turns before attempting any other action for recovery. Before additional measures are tried, the controls should be returned to their original positions and maintained for at least 3 turns so that advantage can be taken of brisk control movements for the second recovery attempt.

For initial spin-test demonstrations, it is customary to install an antispin tail chute to be used in emergency. For an 8000-pound airplane, the chute should be at least 7 feet in diameter, with a 30-foot bridle line. For such demonstration, it is also desirable to have some type of control-position recorder installed during the tests. These instruments have proved very useful in verifying the pilot's impressions of the sequence and magnitude of the control movements in spins, which, at best, are confusing to even highly trained personnel.

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